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(54) IMPROVEMENTS IN OR RELATING TO THE PRODUCTION OF SHAPED ARTICLES

(71) We, NATIONAL RESEARCH DEVELOPMENT CORPORATION, a British Corporation established by Statute, of Kingsgate House, 66—74 Victoria Street, London, S.W.1, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a process for the production of shaped articles, and is more particularly concerned with the production of shaped articles from industrial waste materials.

A variety of industrial waste materials comprise either fibrous or mineral materials, and in many cases mixtures of both. Examples of industrial waste materials include those obtained in paper manufacture, asbestos slurry wastes, food wastes such as coffee waste, tobacco waste and various quarry and mineral wastes. The disposal of these materials represents a serious environmental problem which is increasingly becoming one of national concern.

In British Patent Specification No. 1,275,042 (Application 3851/68) there is described and claimed a method of recovering the fibrous and mineral material in "paper sludge" (the aqueous slurry obtained as a waste effluent in paper manufacture) in which textile and/or mineral fibres with an average fibre length of from $^{1}/_{16}$th of an inch to 5 inches are added to the slurry as individual fibres or as fragments of woven or like fabric so as to assist in agglomerating together the fibre material of the slurry together with at least part of any mineral content thereof, and in which the agglomerated material is recovered as a board product or as a moulding composition.

The present invention provides a process for the production of shaped articles which may be broadly applied to a variety of industrial waste materials.

According to the invention a process for the production of a shaped article from fibrous and mineral industrial waste materials comprises depositing a layer of an aqeuous slurry comprising a mixture of a fibrous waste material component and a mineral waste component and controlling the water content of the slurry so as to produce a coherent agglomerated layer having a degree of wet strength, and then forming the layer under heat and pressure to produce a shaped article.

The invention also comprises an apparatus for the production of shaped articles from fibrous and mineral industrial waste materials comprising a liquid permeable support, extrusion means for depositing a layer of an aqueous slurry comprising a mixture of a fibrous waste material component and a mineral waste material component onto the liquid permeable support, means for controlling the water content of the slurry by applied pressure so as in operation to produce a coherent agglomerated layer having a degree of wet strength, and means for forming the coherent agglomerated layer under heat and pressure.

In a preferred process according to the invention an aqueous slurry comprising a mixture of a fibrous waste material component and a mineral waste material component is deposited on to a liquid permeable support to form a layer, and the water content of the slurry is controlled by applied pres-

sure so as to produce a coherent agglomerated layer having a degree of wet strength. The layer may then be moulded under the action of heat and pressure to produce a shaped article.

The invention may be applied to a wide variety of industrial waste materials and also to mixtures thereof. The fibrous component of the mixture may be organic, for example cellulose fibres derived from waste paper, waste chopped rags, sisal, jute or hessian or synthetic resin fibres for example nylon, Terylene (Terylene is a Registered Trade Mark) or polypropylene fibres; or inorganic for example asbestos fibres or glass fibres. The mineral component may be a clay, for example china clay or micaceous china clay, an oxide, for example silica, titanium dioxide, or antimony trioxide, and various inorganic salts for example silicates and carbonates such as calcium carbonate or chalk obtained as waste products from a wide variety of manufacturing operations. The invention is particularly applicable to the treatment of paper sludge which is an aqueous slurry comprising a mixture of cellulose fibres of short fibre length, and minerals such as clay, chalk or calcium carbonate, titanium dioxide and antimony trioxide. The invention may also be applied to asbestos slurry waste, food wastes, tobacco waste and quarry and mineral wastes as previously mentioned.

In the case of industrial waste materials such as paper sludge, the material is already in the form of an aqueous slurry when it is discharged from the paper mill. It is also possible, however, to make up an aqueous slurry suitable for use in the present invention by dispersing the solid fibrous and mineral components in water. For example shredded waste paper may be mixed with a suitable waste mineral material such as micaceous china clay or fine granite dust and water to form a useful aqueous slurry.

It is of course necessary for the aqueous slurry to contain sufficient quantities of solids to enable it to be agglomerated. Simple tests can be made first on filterability and on solids content and from these tests it can be determined what particular procedure in accordance with the invention can be employed and also whether or not the application of the process of the invention to the particular waste material is commercially practicable.

We have found that it is possible to use slurries containing fibres having an average fibre length outside the range of $^{1}/_{16}$th of an inch to five inches. The nature of the slurry itself determines the particular method of treatment which it is necessary to apply, and addition of further fibrous material or mineral material may be made as desired to give a slurry of the required consistency. We have found that slurries containing a relatively large amount of fibrous material frequently require no further additions, but slurries with a very high mineral content for example certain kinds of paper sludge do however appear to require the addition of extra fibrous material or the like to assist in agglomeration of the slurry and to obtain satisfactory products.

Although the exact proportions vary with the nature of the waste material under consideration, we have found that it is preferable to operate with a slurry having a solids content of from 5 to 30% by weight. Industrially produced aqueous slurries frequently contain only up to about 2% solids and in these cases the slurry will usually need to be concentrated, for example by filtration, to bring the solids content up to a usable value. Of this solids content, the fibrous component preferably comprises from 5 to 95% by weight particularly from 20 to 80% by weight and the mineral component preferably comprises from 95% to 5% by weight particularly from 80 to 20% by weight.

The aqueous slurry is preferably deposited upon a liquid permeable support to form a layer, the solid materials remaining on the support whilst the excess water is allowed to drain off. The slurry may be deposited from a hopper, or preferably an extruder having means for discharging the slurry at a predetermined rate. The liquid permeable support may be a mesh or gauze of metal or plastic material, for example stainless steel mesh or nylon mesh and is preferably movable relative to the discharge orifice of the hopper or extruder. For example the liquid permeable support may be in the form of an endless moving belt of metal or plastic mesh or gauze.

A number of methods of controlling the water content of the slurry are available. For example the slurry may be passed through an extruder equipped with means for removing part of the water content of the slurry prior to deposition of the layer, so that the layer of slurry leaving the extruder is of the desired composition. However in a preferred embodiment of the invention, the liquid permeable support carrying the deposited slurry is passed through a series of pressure rolls producing a plurality of nip actions which progressively squeeze out water from the deposited slurry and control its thickness to produce a coherent agglomerated layer of the desired water content and strength. The water content and thickness of the deposited layer may be controlled by varying the pressure applied by the pressure rolls and by nip setting adjustment. The pressure rolls may be arranged above the deposited layer so as to squeeze the layer between the rolls and the liquid permeable support, or alternatively the rolls

may be arranged in pairs above and below the deposited layer. In an alternative method of controlling the water content of the slurry there may be employed a cylindrical vacuum filter which is partly immersed in the slurry and rotated so as to deposit a layer from the slurry on its circumference. The deposited layer of agglomerated slurry may be removed from the filter in a continuous operation, for example with a take-off knife. In another, though generally less preferred alternative, the layer of slurry after deposition on to a liquid permeable support may be passed through a drying oven to control its water content.

The water content of the slurry is controlled so as to produce a coherent agglomerated layer having a degree of wet strength. The degree of wet strength required of the layer is such that it can be formed under pressure without tearing, and such that it is sufficiently self-supporting to enable it to be handled without disintegration. The layer should, for example, preferably be able to withstand bending to an angle of 90° without cracking. Preferably also the layer should be capable of supporting its own weight to such an extent that an 8 foot x 4 foot section will maintain its integrity with minimal support over each 2 feet of its running length and such that an area of at least about 4 square feet will maintain its integrity when supported only at its edges.

The wet strength of the agglomerated layer is dependent upon its thickness, density and water content, but it has been found in practice that the desired thickness and density can be attained by an appropriate choice of the method of controlling the water content. Thus if pressure is applied to the deposited layer of slurry, the density will be increased and the thickness and water content will be reduced. Alternatively if the water content is reduced by heating, the thickness will be substantially unchanged and the density will be reduced. A few simple experiments will determine what conditions are necessary to achieve an agglomerated layer having the desired thickness, density, water content and wet strength.

It is found in general that the water content of the coherent agglomerated layer of slurry may vary from 15% to 85% by weight, based on the total weight of the layer. In choosing an appropriate water content it is necessary to consider not only the wet strength of the agglomerated layer but also the forming operation which the layer is to undergo to produce the shaped article. At the lower levels of water content the agglomerated layer may be used to form flat products and simple mouldings as described later. For more difficult mouldings, and for a variety of general applications, the water content of the layer should be somewhat higher, for example from 40 to 85% by weight, particularly from 50 to 70% by weight. In this condition the layer still surprisingly can possess the wet strength required to permit it to be handled without disintegration.

The thickness of the agglomerated layer is dependent upon the thickness of the final shaped article and the forming process, but it is usually greater than $^1/_{16}$th inch in order to obtain an agglomerated layer having adequate wet strength. Preferably the thickness of the layer is from $\frac{1}{8}$ to $\frac{1}{2}$ inch.

The process of the invention may also be modified to obtain shaped articles of greater thickness.

Thus, for example:—

(i) A plurality of agglomerated layers may be formed and superimposed one on the other. These are then laminated between pressure rollers to obtain a multiple thickness, or slightly less because of slight spread under lamination pressure.

(ii) A single agglomerated layer is first formed in the usual way and this is then followed by depositing a further layer of aqueous slurry on to the first layer by means of one or more hoppers or extruders situated after the first series of pressure rolls. The composite layer is then passed through further pressure rolls to obtain a laminated coherent agglomerated layer.

The density of the agglomerated layer is dependent upon the density required in the final shaped article and the forming process, but is usually from 0.8 to 2.0 grams per cc.

The coherent agglomerated layer is finally formed under heat and pressure to produce the desired shaped article. Thus the forming operation may comprise passing the layer through pressure rolls to give a board product, or moulding the layer to produce a moulded article. Pressures varying from a few pounds per square inch to several tons per square inch may be used in the forming operation, depending on the desired physical properties of the final shaped article. For boards, pressures of from up to 2400 pounds per square inch have been found to give useful products, whilst for moulded articles the moulding pressure is preferably from 50 pounds per square inch to 2 tons per square inch. It is found that there is usually an optimum working temperature which is generally in the range of from 100° to 190°C. In moulding operations the article is preferably left in the heated mould for a few minutes to allow water to evaporate though his item may be minimised by the use of a perforated mould or by vacuum forming. In a preferred method of moulding the shaped articles, there is inserted between a surface of the mould and a surface of the layer a flexible permeable sheet material and

the layer and the sheet material are together subjected to the moulding pressure.

The process of the invention may be used to manufacture various shaped articles:—

(a) *Insulation fibre board*

This is obtained by heating and lightly pressing an agglomerated layer of relatively low water content, say from 15 to 30% by weight to yield a low-density board which has sound insulation properties, comparable with those of existing commercial insulating board.

(b) *Hardboard-type board*

An agglomerated layer or layers are pressed at a pressure of substantially one-half ton per square inch and subjected at the same time to heating at a temperature of substantially 150°C, to obtain a consolidated product similar to harboard and with similar properties. This hardboard can be laminated to the usual surface finishes including wallpaper, self-adhesive vinyl film or paper of the kind common in home decoration. The layer or board, may be sprayed with resin solution on one or both sides to obtain a resin-rich surface of improved finish.

(c) *Decorative "Formica"-type board product* (Formica is a Registered Trade Mark)

This product is obtained by direct lamination of an agglomerated layer or layers with melamine printed surface papers and phenolic underlay. Pressures of up to one half of a ton per square inch and temperatures of 110 to 170°C may be used depending on the density required in the core of the laminate.

(d) *Packaging board*

If the agglomerated layer is heated and lightly pressed or roller, the resulting sheet is suitable for various types of packaging materials and for box making. For instance, if a groove is routed in the sheet, the material can be hinged at that point to form a righ-angled joint and a complete box can be made by forming the necessary joints in this way. Boxes with a fair degree of strength can also be made by using the hardboard-type board (b) and treating it in the same manner.

(e) *Moulded decorative products*

These products are an extension of the decorative Formica type product. A radiused or ribbed mould may be used and the product takes on the shape of the mould together with a decorative effect. The board may also be embossed. This cannot be done with usual Formica materials as such materials are not mouldable in commercial form.

Examples of articles which can be produced include moulded chair seats and glove box compartments.

Other moulded articles without a decorative finish can also be produced for particular applications, for example pallets can be produced with a high load bearing capacity.

(f) *Construction sheets and boards*

An agglomerated layer or layers pressed at a pressure of about $\frac{1}{4}$ ton per square inch and at a temperature of 165° to give products resembling plasterboard or asbestos board. Products resembling stone or slate can also be produced by an appropriate choice of composition.

A variety of additives may be incorporated into the slurry to improve the properties of the final shaped articles. These include synthetic resins which may be thermoplastic, for example styrene/butadiene resins, acrylic resins, vinyl acetate resins and vinyl chloride resins; or thermosetting, for example phenolformaldehyde resins, melamine formaldehyde resins and urea formaldehyde resins. The resins are preferably mixed with the slurry in liquid form, for example as an emulsion or suspension in water, and precipitated by the addition of a precipitating agent such as alum. The resin content of the slurry may be from 5% to 40% by weight. In the case of styrene-butadiene resin containing formulations, thermoplastic boards may be obtained which can be stamped out to shape after being plasticised by heating. A similar result can be obtained with phenol-formaldehyde resin containing formulations but a "cure-time dwell' is then needed. A preferred resin content of the slurry is then 10% to 40% by weight. A further group of useful additives are flame-retardants, particularly in the production of boards and sections for the building industry. Suitable flame retardants include borates, boric acid, monoammonium phosphate, aluminium hydroxide and other commercially available flame retardent materials. Excellent results have been obtained using leevls of up to about 8% by weight of the flame retardant. We have found that boards made from a composition consisting of at least 63.5% by weight cellulose fibres, 28.5% by weight minerals and up to 8% by weight flame retardant compare favourably with boards made from grade A60 asbestos. It is, of course, possible to obtain boards having good flame retardant properties without the addition of extra flame retardant materials by increasing the proportion of minerals in the composition. Thus compositions containing a minimum mineral content of 55% by weight and 45% by weight fibres have been found to produce board exhibiting excellent flame retardant properties.

If necessary the agglomerated layer may contain a reinforcing medium. For example

a layer of reinforcing fibres such as glass fibres may be deposited upon the agglomerated layer if desired and a light rolling action imparted to the layer to embed the fibres therein. Alternatively reinforcing fibrous layers or "matts" may be laminated on to one or both surfaces of the agglomerated layer or deposited layer of slurry. Suitable reinforcing layers include woven hessian backing or glass fibre matts. As a further alternative the reinforcing medium may be sandwiched between two agglomerated layers and the whole laminate integrated by passage through pressure rolls.

Finally there may be added to the slurry mineral fillers for example silica, quartz or limestone in finely divided form, or pulverised fuel ash. This leads to harder, denser, more fire resistant products.

The invention is illustrated by the following Examples:—

Example 1

This Example describes the production of boards from paper mill sludge.

In determining the fibre and clay contents of various paper making slurries so as to decide on whether or not either fibres or minerals have to be added before the material is converted into board the following analyses were made:—

1. Dickinson Croxley Mill: fibre from 20% to 30% and clay from 80% to 70% by weight.
2. Bowater Thames Mill: fibre from 40% to 70% by weight and clay from 60% to 30% by weight.
3. Mowater Mersey Mill: fibre from 66.6% to 50% by weight and clay from 33.3% to 50% by weight.
4. Bowater Sittingbourne: substantially the same as in the case of Bowater Mersey Mill.
5. Bowater Kelmsley Mill: fibre substantially 84% by weight and clay substantially 16% by weight. The material was mainly from hardboard making.
6. Reeds — Aylesford: the sludge was sampled daily and a composite was tested weekly, over ten weeks, the results were as follows:—

Solids content:	Average 24%
	Range 17 — 35%
Fibre content:	Average 66%
	Range 53 — 76%

The only other major constituent was china clay.

Paper sludge from each individual mill is concentrated and if necessary further fibre or mineral material added. The following are examples of two formulations which are used in the manufacture of various boards products:—

A. *Concentrated Sluge from Reeds Mill*:

Waste paper sludge concentrated to 15% by weight solids content	67 lbs.
Chopped rags ground to ¼" staple length ...	1 lb.
* Phenolic resin CL—151/76 (76% by weight solids content) ...	1½ lbs.
5% by weight Alum solutions ...	600 ccs.

B. *Concentrated Sludge from Bowater Thames Mill*:

Waste paper sludge concentrated to 19% by weight solids content	45 lbs.
Chopped rags ground ¼" staple length ...	1 lb.
* Phenolic resin CL—151/76 (76% by weight solids content) ...	1½ lbs.
5% by weight Alum solutions ...	600 ccs.
3.6% by weight Starch solution	33 lbs.

* CL—151/76 is a 76% by weight solids phenolic resin produced by Sterling Moulding Materials Ltd.

Both the above formulations contain added fibres in the form of chopped rags. However, it is not always necessary to add fibres and for example in the case of the Bowater Kelmsley Slurry (5), it is usually necessary to add a quantity of clay or other minerals to the slurry.

The formulations described above are processed in an apparatus illustrated diagrammatically in Figures 1 to 4 of the accompanying drawings in which:

Figure 1 shows a flow line for the apparatus from the sludge reservoir through filtering, mixing, the conveyor, dopple roller and pressure rollers to cutting and pressing,

Figure 2 shows a flow line of an alternative layout using extrusion, ovens and a multi-daylight press,

Figure 3 shows dewatering of the slurry between top and bottom belts moving between fixed plates and converging on one another, and

Figure 4 shows an alternative arrangement to Figure 3 in which the plates are replaced by an array of pressure rolls acting on the belts from the outside.

Referring now to Figure 1, the apparatus comprises a container for paper sludge which discharges into a rotary vacuum filter in which the sludge is concentrated to a solids content of from 7½% to 30% by weight. From the filter the concentrated sludge is passed to a mixer such as a Gardner Ribbon, Baker-Perkins dough type mixer or alternatively a Hobart dough mixer. In the mixer the various additives such as the phenolic resin are mixed with the sludge and the resulting slurry is then pumped to a storage bin which acts as a feed reservoir for the board manufacturing unit. From the storage bin the slurry is deposited on to a vibrating conveyor in the form of a continuous layer. The layer of slurry carried on the belt of the

vibrating conveyor is then passed through a dopple roller and then through a dewatering device. The dewatering device may comprise a pair of fixed plates forming a continuous nip as illustrated in Figure 3 in which the slurry is conveyed between top and bottom belts thereby squeezing out excess water from the layer of slurry. Alternatively the dewatering device may comprise a series of pressure rolls as illustrated in Figure 4, the layer of slurry again being conveyed through the rolls by top and bottom belts. The nip action of the dewatering device is arranged to be such that the agglomerated layer of slurry leaving the device has the desired thickness, density, and water content. The agglomerated layer of slurry is then cut into boards and stacked to dry. Finally the boards are heated and pressed to form the desired shaped articles and sent for despatch.

An alternative arrangement is shown in Figure 2 in which after mixing of the additives with the paper sludge, the slurry is fed to an extruder feeding mechanism which deposits a predetermined amount of the mixture in the form of a continuous layer which is then conveyed to the dewatering device. The dewatering device reduces the water content of the layer, and when the layer emerges from the device its water content is substantially 45% by weight, i.e. it has a solids content of substantially 55% by weight. The agglomerated layer is then passed to a drying oven where it is dried to an extent sufficient to lower the moisture content to around 15% by weight or less depending upon the properties required of the final shaped article. The continuous agglomerated layer emerging from the oven is then cut into boards and stored for pressing. Finally the boards are heated and pressed in a multi-daylight press and sent for despatch.

Example 2

This Example describes a further process for the production of boards from paper sludge.

Analyses of a variety of paper sludge effluents from commercial paper mills are given in Example 1. These effluents are processed in the apparatus shown diagrammatically in section in Figure 5 of the accompanying drawings.

Referring to Figure 5, the apparatus comprises a slurry hopper 1, provided with an agitator 2, mounted upon the communicating with a screw extruder 3. The extruder has a slit diehead 4 which discharges on to the top surface of an endless stainless steel mesh belt 5. The belt is carried on driven rollers 6 and passes beneath chain driven pressure rolls 7. Water squeezed out of the slurry by the pressure rolls is pumped to a large header tank (not shown) from which any subsequent water demands of the process may be met, or returned to filtration equipment to remove any solids content. The endless belt is provided with cleaning water sprays 8 and rotary brushes 9 on its lower surface. A take-off conveyor 10 adjacent the endless belt leads to pairs of nip rolls 11 and 12 positioned on either side of an automatic cutter 13. From the cutter 13 a series of conveying rollers 14 leads to a power operated loader 15 which feeds a multi-platen daylight press 16. Each platen of the press has a high surface finish and is labyrinth drilled to ensure even heat distribution. An unloader 17 receives boards from the press, and the boards are then transferred to an automatic stacking machine 18.

In operation sludge from the hopper 1 is metered into the screw extruder 3 at a predetermined rate and emerges from the slit diehead 4 as a continuous layer of slurry which is deposited on the endless belt 5. The belt carrying the layer of slurry passes beneath the pressure rolls 7 and water is squeezed out from the layer. The progressive action of the pressure rolls is variable and enables the water content of the layer to be reduced to the desired value. At the same time the action of the rolls controls the thickness and density of the layer. The layer leaves the endless belt and is passed by the conveyor 10 to the nip rolls 11. The cutter 13 automatically cuts the layer into boards of the desired length which are removed by the nip rolls 12 and conveyed by the conveying rollers 14 into the loader 15. The loader inserts the boards into the press 16 where they are heated to a temperature of 160°C and subjected to a pressure of 525 lbs. per square inch. The dwell time in the press is of the order of 15 minutes. From the press the unloader 17 removes the boards which are then stacked by the automatic stacking machine 18.

It is found that excellent boards can be produced from slurries having the following compositions:—

1.	Paper mill sludge (Reeds) 25% solids	40 lbs.
	chopped rags (¼ inch)	1 lb.
	Water (added)	40 lbs.
2.	Paper mill sludge (Reeds) 25% solids	40 lbs.
	Chopped rags (¼ inch)	1 lb.
	Resin CL 164/50	22 lbs.
	Water (added)	40 lbs.
	Alum	600 ccs.
3.	Paper mill sludge (Reeds) 25% solids	40 lbs.
	Chopped rags (¼ inch)	1 lb.
	Pulverised fuel ash	10 lbs.
	Water (added)	40 lbs.
4.	Paper mill sludge (Reeds) 25% solids	40 lbs.
	Chopped rags (¼ inch)	1 lb.

	Mono ammonium phosphate	1 lb.
	Water (added)	40 lbs.
5.	Paper mill sludge (Reeds) 25% solids	40 lbs.
	Chopped rags (¼ inch)	1 lb.
	Pulverised fuel ash	20 lbs.
	Water (added)	40 lbs.

Compositions 3, 4 and 5 have been found to give boards having an excellent degree of flame retardance.

WHAT WE CLAIM IS:—

1. A process for the production of a shaped article from fibrous and mineral industrial waste materials which comprises depositing a layer of an aqueous slurry comprising a mixture of a fibrous waste material component and a mineral waste material component and controlling the water content of the slurry so as to produce a coherent agglomerated layer having a degree of wet strength, and then forming the layer under heat and pressure to produce a shaped article.

2. A process according to Claim 1, in which the aqueous slurry is deposited on to a liquid permeable support to form a layer, and the water content of the slurry is controlled by applied pressure so as to produce a coherent agglomerated layer having a degree of wet strength.

3. A process according to Claim 1 or 2, in which the fibrous component of the mixture comprises cellulose fibres.

4. A process according to any of the preceding claims, in which the mineral component comprises a clay, an oxide or an inorganic salt.

5. A process according to any of the preceding claims in which the aqueous slurry comprises paper sludge.

6. A process according to Claim 5, in which extra fibrous material is added to the aqueous slurry to assist in agglomeration of the slurry.

7. A process according to any of the preceding claims, in which the aqueous slurry has a solids content of from 5 to 30% by weight.

8. A process according to any of the preceding claims, in which the fibrous component comprises from 20 to 80% by weight of the solids content of the aqueous slurry.

9. A process according to any of the preceding claims, in which the mineral component comprises from 20 to 80% by weight of the solids content of the aqueous slurry.

10. A process according to any of the preceding claims, in which the aqueous slurry is deposited from an extruder at a predetermined rate on to a liquid permeable support which is movable relative to the discharge orifice of the extruder.

11. A process according to Claim 10, in which the liquid permeable support comprises an endless moving belt of metal or plastic mesh or gauze.

12. A process according to any of the preceding claims, in which the slurry is passed through an extruder equipped with means for removing part of the water content of the slurry prior to deposition of the layer.

13. A process according to any of the preceding claims, in which the aqueous slurry is deposited upon a liquid permeable support and the support carrying the deposited slurry is passed through a series of pressure rolls which progressively squeeze out water from the deposited slurry to produce a coherent agglomerated layer having a degree of wet strength.

14. A process according to any of Claims 1 to 12, in which a cylindrical vacuum filter is partly immersed in the slurry and rotated so as to deposit a layer from the slurry on its circumference and the deposited layer of agglomerated slurry is removed from the filter in a continuous operation.

15. A process according to any of Claims 2 to 12, in which the layer of slurry after deposition on to a liquid permeable support is passed through a drying oven to control its water content.

16. Aprocess according to any of the preceding claims, in which the agglomerated layer has a wet strength sufficient to withstand bending to an angle of 90° without cracking.

17. A process according to any of the preceding claims in which the wet strength of the agglomerated layer is such that an 8 feet by 4 feet section will maintain its integrity with minimal support over each two feet of its running length and such that an area of at least four square feet will maintain its integrity when supported only at its edges.

18. A process according to any of the peceding claims in which the water content of the agglomerated layer is from 15 to 85% by weight based on the total weight of the layer.

19. A process according to any of the preceding claims in which the water content of the agglomerated layer is from 40 to 85% by weight based on the total weight of the layer.

20. A process according to any of the preceding claims in which the thickness of the agglomerated layer is from ⅛ to ½ inch.

21. A process according to any of the preceding claims in which the density of the agglomerated layer is from 0.8 to 2.0 grams per cc.

22. A process according to any of the preceding claims, in which the agglomerated layer is moulded under heat and pressure to form a shaped article.

23. A process according to any of the

preceding claims, in which the shaped article is a board and the moulding pressure is up to 2,400 pounds per square inch.

24. A process according to any of Claims 1 to 22, in which the shaped article is moulded article and the moulding pressure is from 50 pounds per square inch to 2 tons per square inch.

25. A process according to any of the preceding claims, in which the forming and drying operations are carried out together at a temperature of from 100° to 190°C.

26. A process according to any of the preceding claims, in which the shaped article is moulded by interposing between a surface of a mould and a surface of the agglomerated layer a flexible permeable sheet material and the layer and the sheet material are together subjected to a moulding pressure.

27. A process according to any of the preceding claims, in which a plurality of agglomerated layers are formed, superimposed one on the other and then laminated between pressure rollers.

28. A process according to any of Claims 1 to 26, in which an agglomerated layer is first formed and a further layer of aqueous slurry deposited thereon, the composite layer being then passed through pressure rolls to obtain a laminated coherent agglomerated layer.

29. A process according to any of the preceding claims in which there is added to the slurry from 5 to 40% by weight of a synthetic resin.

30. A process according to Claim 29, in which the synthetic resin is a styrene/butadiene resin, an acrylic resin, a vinyl acetate resin, a vinyl chloride resin, a phenol formaldehyde resin, a melamine formaldehyde resin, or a urea formaldehyde resin.

31. A process according to any of the preceding claims in which there is added to the slurry a flame retardant.

32. A process according to Claim 31, in which the flame retardant is a borate, boric acid, mono-ammonium phosphate, or aluminium hydroxide.

33. A process according to any of the preceding claims in which the agglomerated layer contains a reinforcing medium that is a layer of fibres or a fibrous matt.

34. A process according to any of the preceding claims, in which there is added to the slurry a mineral filler.

35. A process according to Claim 1 substantially as described in Example 1.

36. A process according to Claim 1 substantially as described in Example 2.

37. An apparatus for the production of shaped articles from fibrous and mineral industrial waste material which comprises a liquid permeable support, extrusion means for depositing a layer of an aqueous slurry comprising a mixture of a fibrous waste material component and a mineral waste material component onto the liquid permeable support, means for controlling the water content of the slurry by applied pressure so as in operation to produce a coherent agglomerated layer having a degree of wet strength, and means for forming the coherent agglomerated layer under heat and pressure.

38. An apparatus according to Claim 37, in which the extrusion means comprises an extruder having means for discharging the slurry at a predetermined rate.

39. An apparatus according to Claim 38, in which the extruder is equipped with means for removing part of the water content of the slurry prior to deposition of the layer.

40. An apparatus according to any of Claims 37 to 39, in which the liquid permeable support comprises an endless movable belt of metal or plastic mesh or gauze.

41. An apparatus according to any of Cltims 37 to 40 which comprises means for conveying the deposited slurry through a series of pressure rolls which in operation produce a plurality of nip actions which progressively squeeze out water from the deposited slurry to produce a coherent agglomerated layer.

42. An apparatus according to any of Claims 37 to 41, which comprises means for moulding the coherent agglomerated layer under the action of heat and pressure to produce a shaped article.

43. An apparatus according to Claim 37 substantially as hereinbefore described with reference to and as illustrated in Figures 1 to 4 of the accompanying drawings.

44. An apparatus according to Claim 37 substantially as hereinbefore described with reference to and as illustrated in Figure 5 of the accompanying drawings.

45. A shaped article produced by a process according to any of Claims 1 to 36.

46. A pressure-formable coherent agglomerated layer when formed in a process according to Claim 1 comprising a mixture of a fibrous component and a mineral component, said components comprising industrial waste materials, having a thickness greater than $^1/_{16}$th of an inch, a density of from 0.8 to 2.0 grams per cubic centimetre and a water content of from 15% to 85% by weight, based on the total weight of the layer, the layer being sufficiently self-supporting to enable it to be handled without disintegration.

47. A layer according to Claim 46, in which the fibrous component of the mixture comprises cellulose fibres.

48. A layer according to Claim 46 or 47, in which the mineral component of the layer comprises a clay, an oxide, or an inorganic salt.

49. A layer according to any of Claims 46 to 48, in which the layer comprises paper sludge.

50. A layer according to any of Claims 46 to 49, having a wet strength sufficient to withstand bending to an angle of 90° without cracking.

51. A layer according to any of Claims 46 to 50, having a wet strength such that an 8 feet by 4 feet section will maintain its integrity with minimal support over each two feet of its running length and such that an area of at least 4 square feet will maintain its integrity when supported only at its edges.

52. A layer according to any of Claims 46 to 51, having a water content of from 50% to 70% by weight, based on the total weight of the layer.

53. A layer according to any of Claims 46 to 52, having a thickness of from $\frac{1}{8}$ to $\frac{1}{2}$ inch.

54. A laminate comprising a plurality of layers according to any of Claims 46 to 53.

55. A pressure-formable coherent agglomerated layer according to Claim 46 substantially as hereinbefore described.

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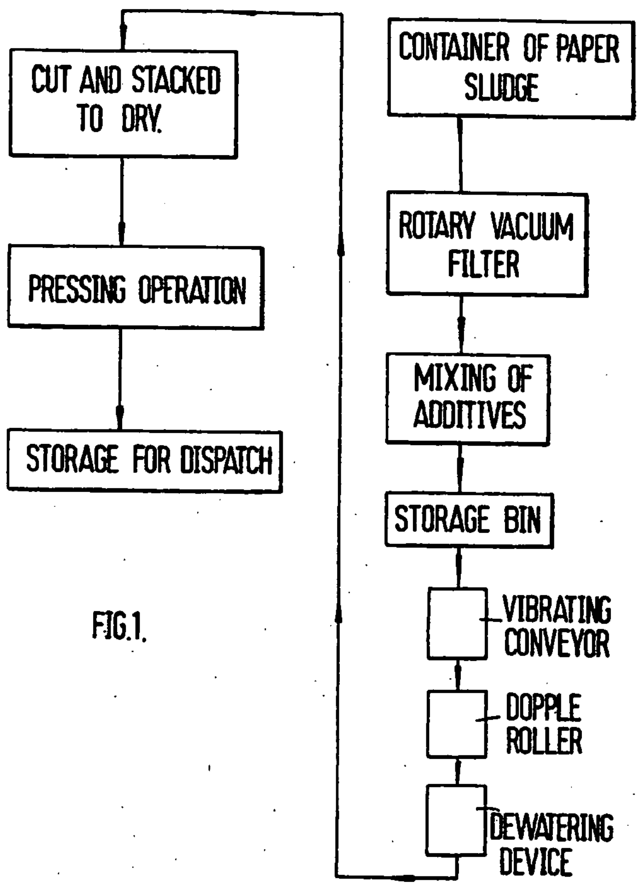
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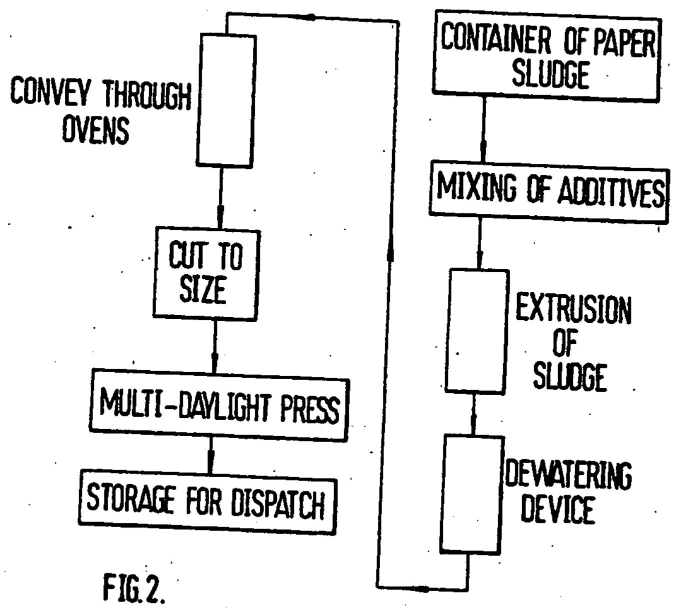
VIBRATING CONVEYOR
DOPPLE ROLLER
DEWATERING DEVICE

FIG.1.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EXTRUSION OF SLUDGE
DEWATERING DEVICE

FIG. 2.

1405587 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3

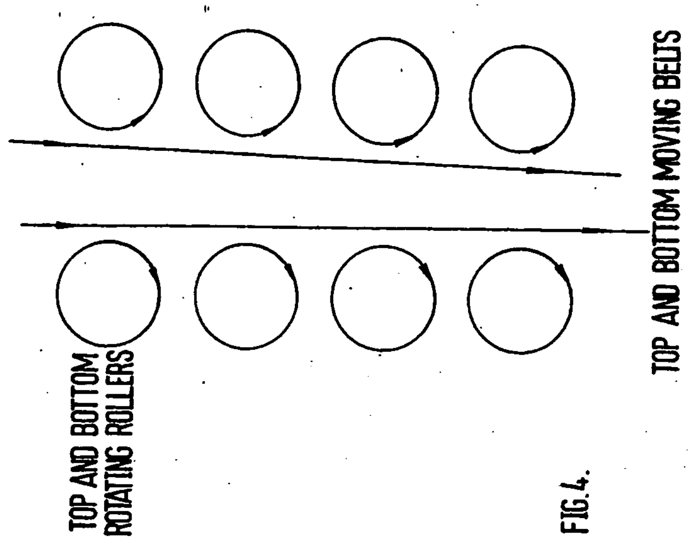

FIG.4.

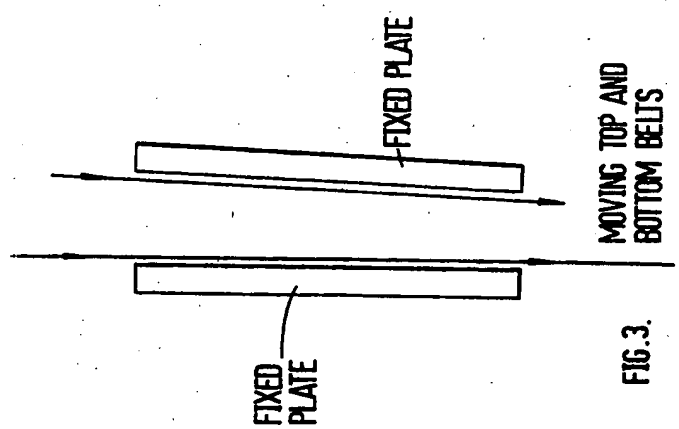

FIG.3.

1405587 COMPLETE SPECIFICATION

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Sheet 4

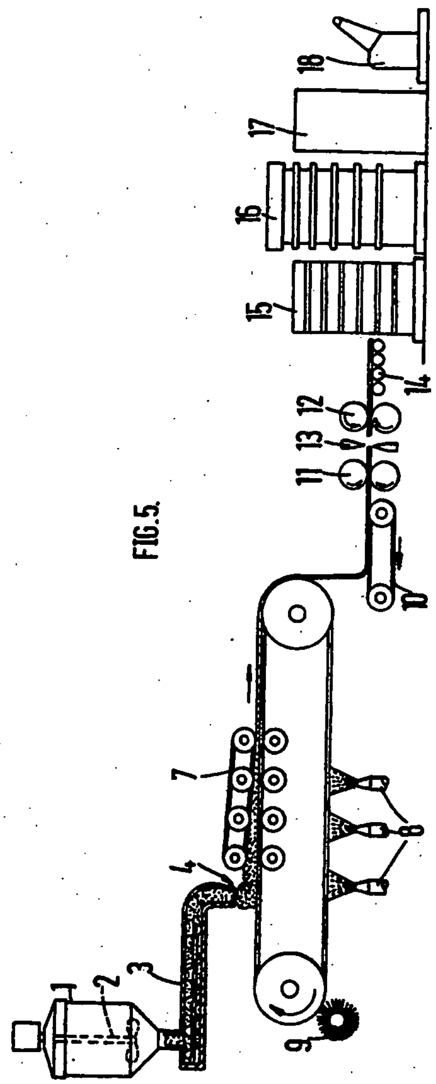

FIG.5.